

ART. XIV.—*The Structure of the Truncus Arteriosus in Species of the genera Hyla, Limnodynastes, Chiroleptes, Heleioporus, Pseudophryne and Notaden.*

By KATHLEEN K. OLIVER.

(With Plates XXXVII-XXXIX).

[Read 9th December, 1909.]

In reading various biological authorities I have noticed a marked discrepancy in the different accounts of the number and relative importance of the valves of the frog's heart.

A. Milner Marshall and Ecker both deal with *Rana temporaria*, and each gives a different number of valves as guarding both the entrance to the Truncus Arteriosus from the Ventricle, and to the Synangium, from the Pylangium.

Bourne, in his description of the frog, does not name the species on which he is working, merely giving the generic name of *Rana*, and differs again in regard to the number of valves from both of the two above authorities.

In the following account a description is given of the structure of the Truncus Arteriosus in representatives of the three families of the Amphibia that are found in Australia. The species examined are as follows:—

Family *Hylidae*.

Hyla aurea.

Family *Cystignathidae*.

Limnodynastes dorsalis.

Heleioporus pictus.

Chiroleptes alboguttatus.

Family *Bufo*nidae.

Notaden bennetti.

Pseudophryne semimarmorata.

My thanks are due to Professor Spencer for his kind help, and for the use of the laboratory and department specimens of

the Melbourne University, also to Mr. John Booth and Mr. J. C. Gilmour, for the live specimens they have been at trouble to procure for me, thus aiding me in investigation with the dissecting microscope.

As regards the nomenclature of the valves to be dealt with hereafter, as no definite names appear to have been hitherto applied to them, I have called those between the Ventricle and the Pylangium the *pylangial valves*, and those between the Pylangium and Synangium, the *synangial*.

The accompanying table will serve to show the discrepancies in the accounts of the valves of the truncus arteriosus given by certain authors.

The interior of the truncus, as is well known, is divided into two parts—the proximal, called the *Pylangium*, and the distal, the *Synangium*.¹ In some species the line of demarcation between these two portions of the Truncus Arteriosus is very distinct externally (Fig. 2), while in others—e.g., *Hyla aurea* (Fig. 1)—there is little or no outward evidence of the division into proximal and distal compartments.

Just to the left of the opening from the ventricle, a dorsally attached septa arises, running the whole length of the Pylangium, and called, from the spiral twist in it, the *spiral valve or fold*. This spiral valve is free ventrally, and normally turns from the right side at the posterior end, to the left at the anterior. At the anterior end of the valve there are more or less well marked valves guarding the entrance to the Pulmo cutaneous arch.

The Synangium is that part of the truncus which is anterior to the spiral valve, and from it arise the systemic and carotid arches. The spiral fold is a constant feature, differing only as to shape and relative thickness in the various genera. The valves at the anterior end of the spiral fold, separating the Pylangium from the Synangium, while constantly present, are

¹ Different authors apply different names to the parts associated with what we call the *Truncus arteriosus*. Marshall, whom we follow, calls the whole structure the *Truncus arteriosus*, and divides it into a proximal part, the *Pylangium*, and a distal, the *Synangium*. Howes confines the term *Truncus* to the proximal part; Parker and Haswell call the proximal part the *Conus arteriosus* and the distal *bulbus aortae*; Holmes calls the proximal part the *bulbus cordis*, and the distal the *Truncus arteriosus*, whilst Ecker calls the proximal part the *Truncus*, though he sometimes applies the same name to the combined proximal and distal parts.

Author	No. of Pylangial Valves	No. of Syngangial Valves	Position of opening of Pulmo- cutaneous Arch
Marshall, "The Frog," 8th ed., 1902. Rana =	3 semilunar	3 semilunar	Syngangium
Howe's Atlas of Pract. Vert. Zoology, 1902, pl. 11. R. esculenta	Number not stated	Number not stated	Pylangium
Sedgewick, "Text-book of Zoology," p. 282. Rana platyrhina	3 semilunar	3 semilunar	Pylangium
Bourne, "Comp. Anatomy of Animals. Rana —	2 semilunar	3, to one of which spiral fold is fused	Opens "just above the middle and smallest of the three valves"
Holmes, "Biology of the Frog," p. 266; diagrams from Parker and Haswell	3	Spiral valve "widens out at its anterior end into a cup-like valve. Two smaller valves occur at the same level"	Copies drawings in Parker and Haswell
Thomson, "Outlines of Zoology," p. 571	"Opening of pylangium into ventricle is guarded by 2 semilunar valves"	Number not stated	Not stated
Parker and Haswell, "Text-book of Biology," p. 259. R. temporaria	3 small semilunar	1 valve, "and by the free end of the longitudinal valve"	"Conus" (= pylangium)
Parker and Parker, "Pract. Zoology," p. 87. R. temporaria	3 semilunar	1 semilunar, and "free flap of longitudinal valve. The pulmo-cutaneous aperture is also guarded by a small valve."	"Conus"
Chalmers Mitchell, "Outlines of Biology," p. 251	3 semilunar	"3 pocket-shaped valves, the openings of which are directed away from the heart."	Aperture of pulmo-cutaneous trunk "immediately behind" the valves
Rolleston, "Forms of Animal Life," ed. by Jackson, p. 76	3 semilunar	3, of which one is the spiral fold. Two other smaller ones, one dorsal, one ventral. A vertical septum placed transversely divides origin of pulmonary arteries from the origin of aortae and carotids.	Pylangium
Eckes, "The Frog," 1st ed., English trans.	2	1	Pylangium

more or less modified in the different genera. In some cases one or other of them seem almost to disappear; in others they appear to be fully developed, and show distinct fusion with the top of the spiral fold.

There is in *Hyla aurea* a modification of the spiral fold, which will be recorded under the detailed account of that genus, and which is interesting physiologically, in that it suggests a theory of the blood flow which as yet does not appear to have been considered. The solid objects are drawn as dissected, and the sections are taken from consecutive series, the most diagrammatic and typical being chosen.

HYLIDÆ.

1. *Hyla aurea*. (Plate XXXVII., Figs. 1, 2, 3, 4, 5, 6.)

The opening from the Ventricle to the Truncus Arteriosus is on the right of the spiral fold, at the extreme proximal end. It is guarded by two laterally placed semi-lunar valves, connected by cordae tendinae, with the inner wall of the Pylangium.

At the anterior end of the spiral fold, guarding the opening to the Pulmo-cutaneous arch, and on the left side of the fold, is one very definite semilunar valve (v.), attached dorsally, and free ventrally, and one small flap of membrane which may be taken as a half valve. It lies to the right of the larger valve, and is fused with it, and lies dorsal to the turned top of the spiral valve, so as to be invisible in a dissection from the ventral side. The spiral valve in *Hyla* is very strongly developed, there being a very definite spiral twist. (Fig. 1.) The free edges are thicker than the main part of the valve, and are softly rounded. It is attached dorsally only, and is free along the whole ventral border. The right hand end of the synangial half-valve fuses with the spiral valve a short distance posterior to the anterior end of its free edge.

The papilla on which the Carotids open (Car.) is most distinct, its edges overlapping the opening to the systemic to a slight extent.

Developed in connection with the spiral valve is an interlocking apparatus, presumably junctioning in conjunction with

the synangial valves in regulating the blood flow through the Truncus.

On the right hand wall of the Truncus a definite, papilla-like structure is present (p), and opposite it on the same side of the fold is a depression (d), into which the papilla fits. Bourne, in his work on *Rana*, states that the Pulmo-cutaneous arch opens from the Synangium, anterior to the spiral valve and its attendant synangial valves; also he figures the valves as facing up towards the cavity of the Synangium.

The synangial valves in the Australian frogs that I have investigated are between the Pulmo-cutaneous arch and the Synangium, and this position, together with the presence of the interlocking apparatus, would suggest the following theory as to the regulation of the blood flow through the Truncus—that when the spiral valve is in its normal position—that is, the position in which there is least pressure exerted on it—and this is when the pressure is greatest in the Synangium, and therefore lower in the Pylangium, the interlocking apparatus is closed, the papilla on the Pylangial wall fitting closely into the depression on the spiral valve. In this position the spiral valve would direct the impure blood, entering first on the Ventricular Systole to the left, and so on up to the Pulmo-cutaneous arch, where the pressure is lowest, the preceding systole having forced the blood on to the lungs. When the Pylangium is full, and the pressure becomes greater than that above in the Synangium, the blood forces up the Synangial valves, and these, being fused with the spiral valve, pull the fold over to the left, thereby opening the interlocking apparatus, and the blood rushes towards the Systemic and Carotid area, there being now less pressure than in the Pulmo-cutaneous entrance.

CYSTIGNATHIDÆ.

1. *Limnodynastes dorsalis*. (Plate XXXVIII., Figs. 9-10.)

In *Limnodynastes dorsalis* there are two very distinct synangial valves (Fig. 9 v¹v²). The valve attached to the left side of the Truncus is large, semi-lunar, and definite, and that further to the right is smaller, its right hand end fusing with the anterior end of the spiral valve. Both valves have their cups

directed inwards towards the cavity of the Pylangium guarding the entrance to the pulmo-cutaneous arch, as is the case in all other genera I have worked in the Australian frogs.

The Pylangial valves (Fig. 10 v¹v²) are characterised by the presence of two distinct papilla-like structures (Fig. 10 p.p¹), one at the dorsal, and one at the ventral junction of their lips.

The interlocking apparatus is represented in this genus by a somewhat thicker attachment of the spiral valve to the dorsal wall, the ventral surface of which is slightly rounded, so as to fit into the curve of the spiral valve on the right side when that structure swings over from the left.

The fold itself is much less definitely spiral than that of other genera. The edges are very blunt, and the main part much thicker than in the case in *Hyla*. The carotid papilla also is less well defined than in the other Australian genera worked.

2. *Helioporus pictus*. (Plate XXXVIII., Fig. 12.)

In *Helioporus pictus* the edges of the spiral valve are sharply marked and definite, and there is a decided right to left spiral twist. The Pylangial valves are two in number, with a small papilla on the dorsal wall of the opening, and a less well-defined and smaller one on the ventral.

Two synangial (Fig. 12 v¹) valves are present, each of a very indistinct transparent and membranous appearance, and each of approximately the same size. The right one is attached at the right side to the anterior end of the spiral valve, at its ventral margin, and the other end is fused with the left hand valve just above the opening to the Pulmo-cutaneous arch.

The interlocking apparatus is most indefinite in this genus, being represented by a slight indentation on the fold and a very slight thickening of the wall opposite it, much as in *Lymnodynastes dorsalis*.

3. *Chiroleptes alboguttatus*. (Plate XXXIX., Fig. 14.)

In this genus the carotid papilla (car.) is very marked. The spiral valve is not at all well developed, there being very little spiral twist present.

The interlocking apparatus is faintly marked, the papilla-like structure on the wall of the Truncus being the only indication of it. There is one very definite synangial valve on the left lateral, and ventral side (Fig. 14 v.¹), and a narrow flap of skin fused to the top of the spiral fold on the right and attached across the dorsal side of the Truncus just above the opening of the Pulmo-cutaneous arch. (Fig. 14 v.²) The semilunar valves are placed laterally, without any dorsal and ventral papillae. Taken altogether, this genus appears to be further from the usual structure of the Truncus than any of the so far worked families or genera.

BUFONIDAE.

1. *Notaden bennetti*. (Plate XXXIX., Fig. 15.)

The spiral fold is here most definitely curved, and has a thick, coarse edge.

The interlocking apparatus is represented by a very faint papilla on the wall of the Truncus, opposite the top curve of the spiral fold, into which it presumably fits, instead of having a separate indentation as in other genera.

The synangial valves (Fig. 15 v¹v²) are two in number, both approximately of the same size. The right end of the right valve being, as usual, fused to the spiral fold, and attached at its left end to the spot from which the left valve springs. The spot at which the right and left valves join each other is immediately above the opening of the Pulmo-cutaneous arch.

The Carotid papilla is very marked, and relatively large. The semilunar pylangial valves (Fig. 16 v¹v²) are closely opposed when shut, there being no papillae on the dorsal and ventral sides.

In a longitudinal horizontal section (Fig. 17), the very distinctly spiral form of the spiral fold will be clearly seen.

2. *Pseudophryne semimarmorata*.

This genus is too small for dissection, so the structure can only be arrived at by means of sections.

There are apparently two synangial valves (Fig. 18 v¹v²), much the same as in other genera, and the spiral valve seems

to be less curved than is usually met with in the other Australian frogs so far investigated.

The carotid papilla is present, but does not appear to be exceptionally large.

SUMMARY OF RESULTS.

The Truncus Arteriosus is divided into two distinct portions—the proximal Pylangium, between which and the Ventricle are the Pylangial valves, and the distal portion or Synangium, separated from the Pylangium also by valves. It is chiefly with these valves and associated structures that this paper deals. Various authors (see Table) have worked out these valves in *Rana*, and the result has been such that a marked discrepancy is apparent. Also there appears to be some doubt as to the relative position of the Synangial valves and the Pulmo-cutaneous opening. Some authorities depict the Pulmo-cutaneous opening in the Synangium, and the cups of the valves facing anteriorly; some place it in the Pylangium, with the cups of the valves facing posteriorly. As these two positions would necessarily give totally different methods of the blood flow through the Truncus, it is of importance to ascertain the positive position of these parts.

In the Australian frogs worked there is a constant number of Pylangial valves (2), and also of Synangial valves (2), the structure and development in the different genera only being subject to variation. In every individual investigated, the Pulmo-cutaneous arch has opened from the Pylangium, and has been guarded by the Synangial valves which face posteriorly, towards the cavity of the Pylangium. This position of the Pulmo-cutaneous arch in relation to the Syangial valves, together with the interlocking structure, suggests the above-mentioned theory of the blood flow through the truncus.

In the following table the number and importance of Pylangial and Synangial valves is indicated, together with the position of the Pulmo-cutaneous aperture in the specimens examined.

Family	Genus and sp.	Pyngial Valves	Synangial Valves	Aperture of P.C.
Hylidae	<i>Hyla aurea</i>	2	1 + small $\frac{1}{2}$ valve	Pyngium
Cystignathidae	<i>Limnodynastes dorsalis</i>	2, with distinct papillae	2	Pyngium
	<i>Heleioporus pictus</i>	2, with small papillae	2	Pyngium
	<i>Chiroleptes alboguttatus</i>	2	1 distinct and 1 poorly developed	Pyngium
Bufonidae	<i>Notaden bennetti</i>	2, with no papillae	2	Pyngium
	<i>Pseudophryne semimarmorata</i>		2	

LIST OF WORKS REFERRED TO.

- A. Milner Marshall.—“The Frog,” 8th ed., 1902.
 Howes.—“Atlas of Practical Vertebrate Zootomy,” ed. 1902, plate II.
 Sedgwick.—“Student’s Text Book of Zoology,” p. 282.
 Bourne.—“Comparative Anatomy of Animals.”
 Holmes.—“Biology of the Frog,” p. 266.
 Thomson.—“Outline of Zoology,” p. 571.
 Parker and Haswell.—Vol. II. “Text Book of Biology,” p. 259.
 Parker and Parker.—“Practical Zoology,” p. 87.
 Chaimers Mitchell. “Outlines of Biology,” p. 251.
 Rolleston.—“Forms of Animal Life,” ed. by Jackson, p. 76.
 Ecker.—“Anatomy of the Frog,” ed. George Haslam, 1888.

EXPLANATION OF PLATES.

List of abbreviations used.

- P = Pyngium.
 S = Synangium.
 Car = Carotid Papilla.

- V¹ = first valve.
 V² = second valve.
 p = papilla on wall of Pylangium.
 d = depression on spiral fold opposite p.
 p¹ = papilla at Pylangial valves.

PLATE XXXVII.

- Fig. I.—Heart of *Hyla aurea*, showing no outward line of demarcation between the Pylangium and Synangium.
 Fig. II.—Heart of *Limnodynastes dorsalis*, showing distinct outward line of demarcation between Pylangium and Synangium.
 Fig. III.—Drawing of a dissection of the Truncus Arteriosus of *Hyla aurea*, seen from ventral surface.
 Fig. IV.—The posterior end of the Truncus Arteriosus of *Hyla aurea*, showing the Pylangial valves.
 Fig. V.—Truncus Arteriosus of *Hyla aurea*, showing the interlocking apparatus open.
 Fig. VI.—Truncus Arteriosus of *Hyla aurea*, dissected from the ventral aspect, showing the interlocking apparatus shut.

PLATE XXXVIII.

- Fig. VII.—Longitudinal horizontal section of *Hyla aurea*, to show the Synangial valves.
 Fig. VIII.—Longitudinal horizontal section of *Hyla aurea* heart, to show Pylangial valves.
 Fig. IX.—Truncus Arteriosus of *Limnodynastes dorsalis*, to show Synangial valves.
 Fig. X.—Truncus Arteriosus of *Limnodynastes dorsalis*, to show Pylangial valves.
 Fig. XI.—Longitudinal Horizontal section of Truncus Arteriosus of *Limnodynastes dorsalis*, to show the Synangial valves.
 Fig. XII.—Truncus Arteriosus of *Heleioporus pictus*, to show Synangial valves.

PLATE XXXIX.

- Fig. XIII.—Compiled longitudinal horizontal section of *Heleiporus pictus*, to show Synangial valves.
- Fig. XIV.—Truncus Arteriosus of *Chiroleptes alboguttatus*, to show Synangial valves.
- Fig. XV.—Truncus Arteriosus of *Notaden bennetti*, to show Synangial valves.
- Fig. XVI.—Truncus Arteriosus of *Notaden bennetti*, to show Pylangial valves.
- Fig. XVII.—Longitudinal horizontal section of Truncus Arteriosus of *Notaden bennetti*, to show Synangial valves.
- Fig. XVIII.—Longitudinal horizontal section of Truncus Arteriosus of *Pseudophryne semimarmorata* to show Synangial valves.